DVD – the Megastore

with a great future

By Harry Baggen

After the Digital Versatile Disk (DVD), a marriage of the Super Density CD from Toshiba/Time Warner and the Multimedia CD from Sony/Philips, had been introduced at the Consumer Electronics Show in Las Vegas in early 1996, there was much wrangling among producers, computer companies and film makers to agree on a single world standard. Once that was agreed, DVD players appeared on the market in early 1998, but, originally, their adoption by consumers was slow. This was mainly because there were not many pre-recorded DVD's available. However, that situation has changed and over the past two years the sale of DVD players has really taken off.

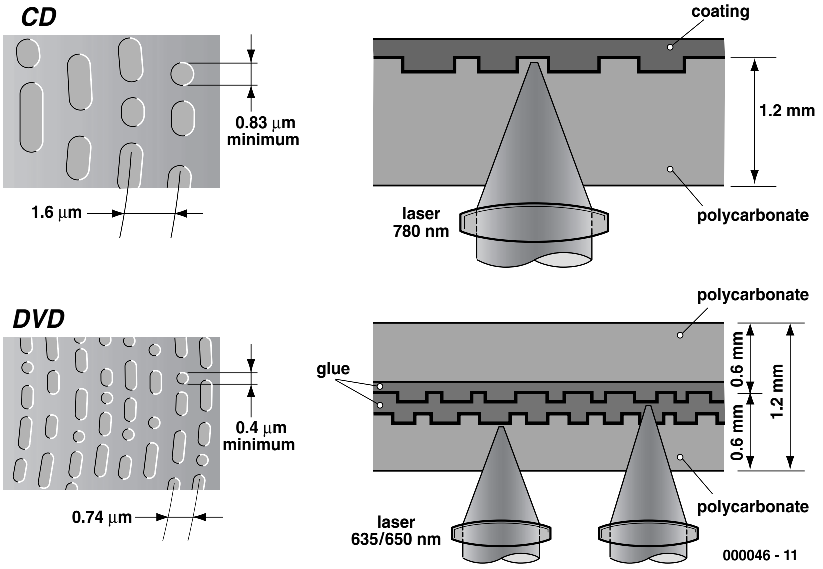


Figure 1. A DVD may consist of up to four layers, two at either side. Shown are the most important physical properties of a DVD compared with those of a CD.

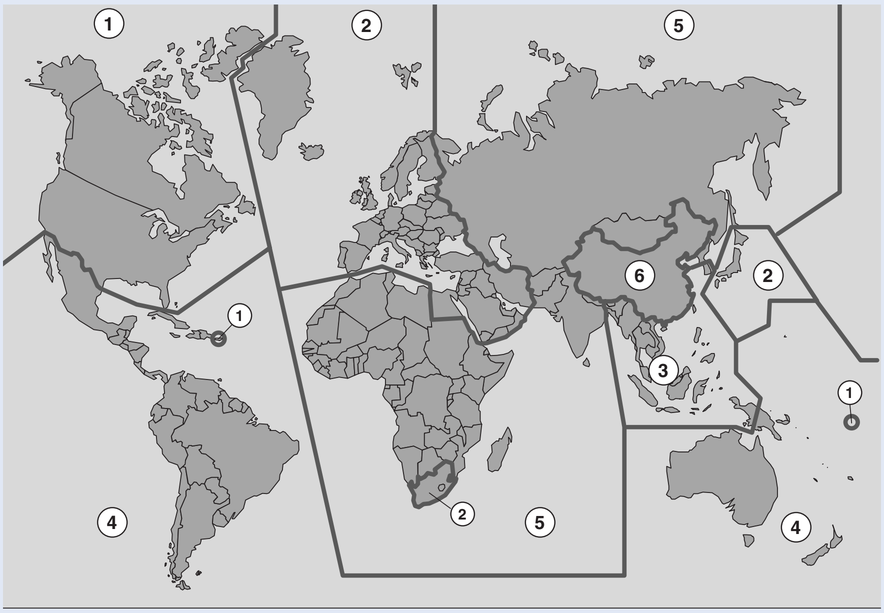
Although the storage capacity of a Compact Disk (CD) at 650 Mbyte appears very large, it is much too small for storing multimedia (combinations of graphics, pictures and sound) data. More especially, it is totally inadequate for storing a complete motion picture with good quality. There have been attempts to store a motion picture onto a CD in MPEG-1 (Moving Pictures Experts Group) format, but this was a complete failure owing to non-availability of suitable domestic players, software, and lack of interest from potential buyers. Moreover, the quality of reproduction was poor and a motion picture of 90–120 minutes duration needed two disks.

The DVD introduced in early 1996 at the Las Vegas Consumer Electronics Show was made possible by improved semiconductor lasers and enhanced CD technologies. With a storage capacity of 4.7–17 Gigabytes, these disks can store up to 11 times as much information as a CD, sufficient for recording a complete, high-quality motion picture, combined with a number of audio channels and some miscellaneous features such as subtitles and simultaneous viewing angles.

In Europe, America and Japan, the popularity and sales of DVD players (for DVD-Video) have risen dramatically over the past year or so. In Britain, sales figures run into many tens of thousands. The main reasons for this acceleration are the growing availability of prerecorded motion pictures, TV Drama, and Concerts, and rapidly falling prices (a good DVD-Video player can be had from about £180 upwards; prices of DVD-Video titles are roughly the same as those for similar Video Tapes) . Although Europe is way behind the United States in this respect, at the time of writing (April 2000), there are over 1500 DVD-Video titles available from distributors and producers like HMV, Choices Direct, Towers, and others, in Britain, and this figure is expanding daily. In the

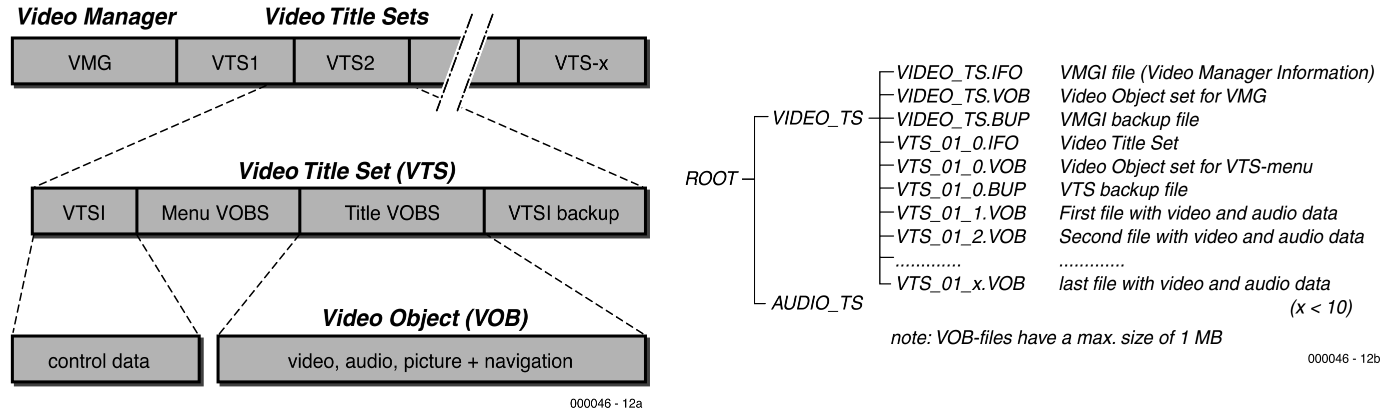
Regional coding

The film industry has had considerable influence on the DVD standard in respect of copy protection and regional protection. The latter gave the industry the opportunity of determining when a certain motion picture would be introduced in a certain region of the world. To this end, the DVD standard contains a regional code for each of six regions of the world. A DVD with one of these codes can be played only on a DVD player with the same code. Already, there are a number of organizations that specialize in converting standard DVD players into players that no longer react to the regional code of a DVD. Computer users are not affected since there are a number of programs that enable changing the regional setting of most software DVD players in a straightforward manner.



Regional codes

0	whole world
1	USA, Canada
2	Europe, Middle East, South Africa, Japan
3	Southeast Asia, Taiwan
4	Central and South America, Mexico, Australia, New Zealand
5	Russia, Africa (other than South Africa), India, Pakistan
6	China


Video Manager
Video Title Sets
VMG
VTS1
VTS2
VTS-x
Video Title Set (VTS)
VTSI
Menu VOBS
Title VOBS
VTSI backup
Video Object (VOB)
control data
video, audio, picture + navigation
000046 - 12a
ROOT
VIDEO_TS
AUDIO_TS
VIDEO_TS.IFO VMGI file (Video Manager Information)
VIDEO_TS.VOB Video Object set for VMG
VIDEO_TS.BUP VMGI backup file
VTS_01_0.IFO Video Title Set
VTS_01_0.VOB Video Object set for VTS-menu
VTS_01_0.BUP VTS backup file
VTS_01_1.VOB First file with video and audio data
VTS_01_2.VOB Second file with video and audio data
....
VTS_01_x.VOB last file with video and audio data
(x < 10)
000046 - 12b

note: VOB-files have a max. size of 1 MB

Figure 2. The data structure of a DVD-Video or DVD-Audio is well defined and consists of two directories that contain the various files as shown.

United States, there are over 5000 available, but no doubt the two markets will gradually converge.

Although most new PCs have a DVD slot, the DVD-ROM has been far less successful: most DVD players incorporated in PCs are (mis)used to view films on a monitor via a software decoder. Moreover, there are few computer games available on DVD-ROM and even fewer encyclopedias make use of the medium. On the other hand, some British computer magazines have begun to issue their monthly issues with a DVD-ROM instead of a standard CD-ROM.

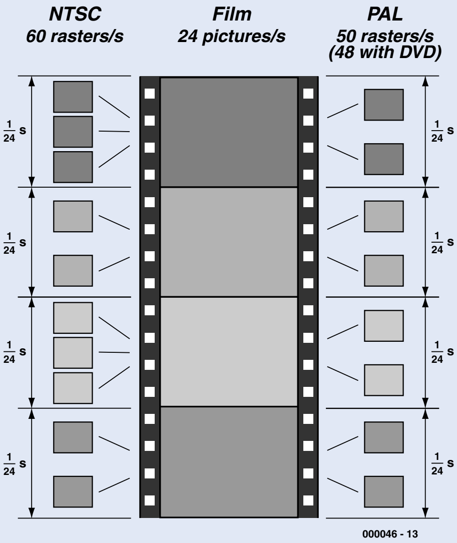
The technology

The DVD and CD have much in common: they are the same size (12 cm dia), which makes them identical in appearance, and use the same basic optical storage technology in which information is represented by microscopic pits. However, there the similarities end.

The minimum length of the pits on a CD is 0.83 μm and on a DVD only 0.4 μm. (Because of the smaller size of the pits, the wavelength of the laser used in a DVD player is smaller than that used in a CD player: 635–650 nm instead of 780 nm). This results in a density of 6300 tracks cm^{-1} on a CD and 13,400 tracks cm^{-1} on a DVD. Since the recording surface is 33 mm wide, a CD contains about 20,000 tracks, and a DVD, 44,000 tracks. The distance between adjacent tracks on a CD is 1.6 μm, whereas that on a DVD is 0.74 μm. A CD contains about 7×10^9 bits, whereas a DVD can store up 38×10^9 bits per layer (it has up to four layers which may be recorded separately).

The substrate of a DVD is a 0.55 mm thick disk of polycarbonate, which, because of the shorter wavelength of the laser, is rather thinner than that of a CD. This is covered by a reflective film which contains the pits. Since each reflective layer has a storage capacity of 4.7 Gbyte, constructions of several layers are possible to increase the storage. In the most common construction, two layers are mounted together separated by a distance of 0.5 μm. The lower of these is semi-reflective (30% reflection). When the DVD is played back, the laser starts by reading the first layer from inside to outside, switches over to the second layers, and reads this from outside to inside. This way of operation enables the switchover time of the

From motion picture to video



Converting a motion picture into video throws up the problem that the former consists of 24 frames per second, whereas the NTSC system uses a field frequency of 60 Hz, and the PAL system one of 50 Hz.. This problem is solved as follows.

In the case of NTSC, each motion picture frame is shown alternately during 2 or 3 video rasters. This results in 12×2+12×3=60 video rasters or 30 frames per second. Actually, the NTSC field frequency is 59.97 Hz, but the difference is small enough to be negligible.

In the case of PAL, the situation is rather more complex. Converting 24 frames to 50 rasters does not result in a clean ratio. However, an interesting solution for this has been found. Each motion picture frame is shown during 2 video rasters, resulting in 48 rasters or 24 frames per second. When such a motion picture is played back, both film and sound are 4% too fast, resulting in an hour long motion picture lasting only 57.6 minutes. In the case of video, this is deemed acceptable, and the sound is adapted during the production of the DVD (assuming that the manufacturer does his job properly).

laser to be kept to a minimum.

A DVD may also be double-sided with one or two reflective layers on either side. This results in up to four layers with a maximum storage capacity of 17 Gbyte. The manufacturer can therefore produce a single-sided DVD with one or two layers, or a double-sided DVD with 1–4 layers. (See Table)

Type	layers	sides	capacity
DVD-5	1	1	4.7 Gb
DVD-9	2	1	8.5 Gb
DVD-10	1	2	9.4 Gb
DVD-18	2	2	17 Gb

Note that in case of a two-layer construction the full capacity is not available.

Irrespective of the number of layers, a DVD consists of two 0.55 mm thick substrates that are firmly glued together to give an overall thickness of 1.2 mm – the same as a CD.

Currently, three types of DVD are in use:

- DVD-Video for motion pictures and concerts; with a single layer this can store up to 130 minutes of images, three audio surround channels, and four subtitles; with two layers up to 240 minutes of recording may be stored.
- DVD-Audio for high-quality audio recordings. Since the storage format is different from that of a DVD-Video, a modified DVD player is needed.
- DVD-ROM for storing computer data. Apart from pure data, it may also contain a mixture of data, sound and pictures/graphics.

Structure

The layout of a DVD depends on the application. In a DVD-ROM, for instance, the norm and data structure are the same as those of a CD-ROM, that is, to ISO9660. In the case of a DVD-Video or DVD-Audio, a layout is prescribed that must be adhered to strictly by the producer—see **Figure 2**. The Audio_ts file is intended for audio files on a DVD-Audio. Up to now, no producer has made use of this. The audio DVDs on the market are really video DVDs on which the sound has been stored in a video file with a sampling rate of 49 kHz or 96 kHz (often only a still picture is then available).

The VTS (Video Title Set) file contains the control data and video objects of the available menus and titles. A DVD may contain more than one VTS file. The actual pictures, sound, and any miscellaneous matters, are contained in the VOB file. During playback, the DVD machine follows the navigation instructions passed to it by the DVD via the menu structure.

The dvd-video

Since the DVD-Video is by far the most important DVD medium, the reader will no doubt appreciate some more details of this.

The images on a DVD-Video are compressed according to the MPEG-2 standard, otherwise a DVD layer could contain only three minutes of pictures. In MPEG-2, the image resolution is 720×480 pixels in the case of NTSC and 720×576 pixels in PAL. There are also a number of smaller resolutions in the standard, but in the vast majority of DVD-Video the stated resolutions are used.

A single-sided, single-layer disk can contain up to 130 minutes of pictures and sound; with two layers, up to 240 minutes.

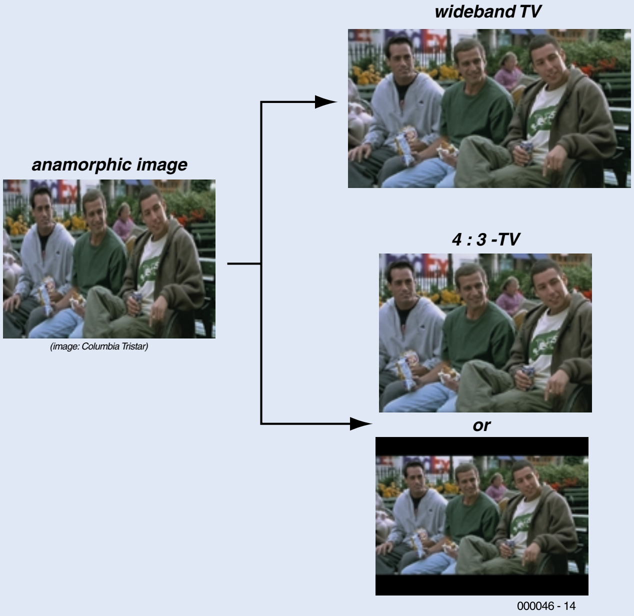
The maximum permissible bit rate is 9.8 Mbit/s, but this is not always used: the average data rate is 4.7 Mbit/s. The actual rate depends, among others, on the number

Bye, bye to the black bars?

A wideband film can be viewed on a standard TV set with 4:3 aspect ratio in a number of ways. The usual way is reproducing the film with the familiar black bars at the top and bottom of the picture (as it were, through a letterbox), but there are alternatives.

Letterbox and pan&scan

Most DVD players have a 'letterbox' setting. When this is enabled, the sides of the picture are cut off so that only the centre portion of the picture is seen. Since this is often inconvenient, not to say annoying, the pan&scan method was developed. In this, the sides of the picture are also cut off, but during the making of the master DVD an indication is given at each frame if the particular frame must be shown to avoid important details getting lost. This method is a good solution to the problem but there are few DVD-Video titles in which the maker has taken the trouble of incorporating it.



(image: Columbia Tristar)

Anamorphic or with black bars?

The PAL standard assumes an aspect ratio of 4:3. When a wideband motion picture is viewed, there will be black bars at the top and bottom of the screen. In a widescreen TV set the picture can be enlarged until it fills the screen, but this affects the resolution since a number of picture lines are then not used. Since DVD-Video players have to convert the MPEG-2 data to PAL or NTSC in any case, the manufacturers have devised a trick. Motion pictures are horizontally compressed onto a DVD-Video so that the original wideband image fits in a 4:3 screen. During playback, the viewer can choose how the film is to be shown. In a widescreen TV set the lines are stretched by the DVD player to such an extent that a 16:9 aspect ratio is obtained. In this way, all picture lines are used optimally. In case of a 4:3 TV set, the DVD player converts the data in such a way that a complete picture is shown with black bars at the top and bottom just as is the case with a wideband TV transmission.

Sequential scanning

Computer monitors give a much more stable and clearer picture than a TV screen, since they use sequential scanning, that is, produce the entire picture in a single field (or raster). Most TV systems use a system interlaced scanning. In this, the lines of successive rasters are not superimposed on each other, but interlaced: two rasters form a complete picture or frame. The number of complete pictures per second is the frame frequency, which is half the number of rasters per second, that is, half the field frequency. Since the rasters are accurately interlaced, and the phosphorous film inside the TV tube has a certain delay time, human eye perceives this as a complete picture. The interlacing scanning is necessary owing to the limited bandwidth of the television broadcast channels.

In a computer system, the graphics card sends 60, 75 or even 100, frames per second to the monitor which results in a highly stable picture. Although the material on DVD-Video disks is made up of frames, the DVD player has to convert these into the requisite rasters for the TV set. Fortunately, sequential scanning is beginning to make an entree into the world of television and TV sets processing frames rather than rasters are becoming available, for instance, from Hitachi. Unfortunately, current DVD players must be modified to deliver frames to such a TV set. Manufacturers of current generations of DVD players have realized this too late, but there are specialist firms who can supply suitably modified DVD-Video players.

of audio channels used.

The pictures may be decoded to the NTSC or PAL standard, which affects not only the resolution, but also the number of frames to be reproduced per second. In the case of NTSC, this number is 30, and with PAL, 25. The manner in which pictures at a rate of 24 frames/sec are converted to 30 or 25 video frames is described in a separate box (*From motion picture to video*).

Several aspect ratios may be used, depending on the the kind of film that is to be reproduced. To ensure compatibility between standard 4:3 TV sets and widescreen sets, there are several ways in which the picture can be stored on the DVD, for instance, with 4:3 pictures, with or without black bars (at the top and bottom of a standard set showing wideband film), or by the anamorphic method.

Since there are a number of different formats in use, it is not always possible to faithfully reproduce a picture on a standard or wideband TV receiver (without black top and bottom strokes and without losing a portion of the image).

format	
1.33:1 (4:3)	standard TV
1.66:1	wideband transmission for standard TV sets
1.78:1 (16:9)	wideband TV
1.85:1	wideband cinema format
235:1	super wideband cinema format

The player provides various playback facilities to adapt the picture to the wishes of the viewer and to the aspect ratio of the TV set being used, such as wideband, letterbox, and pan&scan. Even the least expensive DVD-Video player on the market is 16:9/4:3 switchable.

A motion picture may contain up to nine different camera angles; the viewer can, by a push on a knob, view a certain situation on screen from up to nine different angles. The video images at the various camera positions are stored in series in the VOB file. In the case of two viewing angles, a frame of either is available in the file and the viewer can determine which of these he/she wants to be shown.

Subtitles may be considered as a sort of still picture superimposed on the moving pictures. A DVD-Video may contain up to 32 different subtitles (for instance, 32 different languages).

There are also a number of audio features. Most modern motion pictures use surround sound in 5–7 channels and an additional subwoofer channel. Various standards are used: Dolby Digital (also called AC-3), DTS, and MPEG-2 The latter is hardly used nowadays. Dolby Digital and DTS offer roughly the same facilities, but since it uses a different compression method (and a larger data stream), DTS gives a slightly better sound quality according to some experts. However, in Europe, DVD-Video titles with DTS sound are currently virtually unobtainable.

Good stereo sound reproduction may also be obtained with linear two-channel PCM (Pulse Code Modulation) coding. With this, sampling rates of 48 kHz and 96 kHz, and resolutions of 16, 20 and 24 bits are possible.

The film maker may use a number of camera angles, various sound channels, several subtitles, and some other facilities, as long as the data rates just stated are not exceeded.

Each DVD-Video is copy-protected via a Content Scrambling System (CSS) which senses whether the relevant playback machine is permitted to read the disk. However, this supposedly watertight system was cracked last year by a 15-year old schoolboy. This is, however, no tragedy because the requisite hardware and computing power for copying a DVD-Video is appreciable, apart from the fact that there are currently no affordable recording machines with the same capacity as the DVD available.

A number of DVDs are also fitted with Macrovision protection that causes interference when a DVD is being copied to an analogue video cassette recorder (VCR).

The future

In the foreseeable future, the DVD-Video will no doubt become the mainstay of prerecorded feature films, TV Drama and Comedy, Musicals, and Documentaries; already, in Britain there are more than 1500 titles available and more are added daily.

What is currently lacking to make the takeover from the VCR complete is a suitable recorder. These have recently gone into production with various manufacturers and some are already available in the shops: the DVD-RW from Pioneer; the DVD-RW from Philips; and the DVD-RAM from Panasonic. It will, as usual, take some time before the manufacturers have agreed on a standard.

Currently, prices are high: about £1500–2000 ($US2000–2700) for a recorder and £15–20 ($US20–27) for a re-recordable DVD. However, these prices are likely to tumble before very long when production (after standardization) gets into full swing. Once that is the case, the days of the ageing VCR are numbered.

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